PALMS Standard Operation Procedure

GIS Methodology for mapping Biotic Integrity and Indicator Taxa across watersheds in the eastern USA

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Revision #	Date	Revision Summary	Revised by
0.1	2008_09_11	Initial version	Greg Fiske
0.5	2009_02_14	Revisions based on NPS feedback	Greg Fiske
1.0	2009_03_12	General editing	Scott Goetz

Introduction

The following exercise allows a Geographic Information System (GIS) user to predict the Benthic Index of Biological Integrity (BIBI) and the number of sensitive indicator taxa (*Ephemeroptera*, *Plecoptera*, and *Tricoptera* species) (nEPT) for a given watershed. BIBI and nEPT are two widely used measures of benthic community health. BIBI values range from 1 to 5 with the higher values representing better water conditions that support a wider range of biota. Likewise, high values in nEPT (which ranges from 0 to 25), also indicate stream habitats that can support taxa that are known to be more sensitive to pollutants associated with urbanization and other drivers of stream degradation.

The models described here were derived from data sets on land cover and benthic stream habitat in the state of Maryland, USA. The stream data were collected and compiled by the Maryland Biological Stream Survey program, which has what is widely recognized as the most advanced program of this sort in the nation. Additional information on stream sampling procedures, metadata and data distribution can be found in Roth et al. (2004) and at the MBSS web site: http://www.dnr.state.md.us/streams/mbss

This standard operating procedure (SOP) assumes the reader / user has a 'watershed boundary' spatial data layer for their area of interest. This layer should define relatively small (high stream order) watersheds that are comparable in size to the typical watershed boundaries sampled by the MBSS (i.e. HUC 12).

All the examples provided here are based on use of ArcGIS (v9.3) software, as it is very widely used and can handle both the raster (e.g. land cover) and the vector (watershed) data sets required. ArcGIS includes ArcMap, ArcToolbox, and ArcCatalog.

Data Acquisition and Preprocessing

1) Download NLCD2001 Land Cover data

The national Land Cover Data set (NLCD) is available at the U.S. Geological Survey's Multi-resolution Land Cover (MRLC) website: http://www.mrlc.gov/nlcd_multizone_map.php

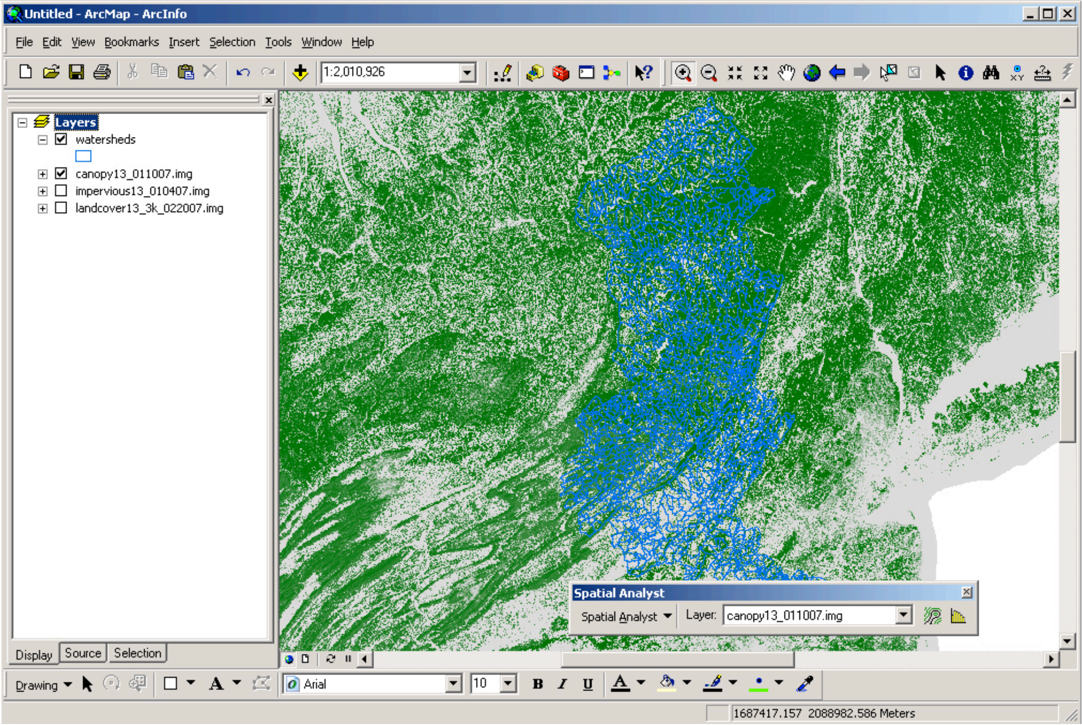
The data sets are divided into 15 regions across the country. Download the percent urban imperviousness, tree canopy, and land cover files for your region. Unzip these files into your working directory on your hard disk. The data are provided in .img format, which is native to Erdas Imagine image processing software as well as ESRI® ArcGIS Desktop software.

2) Match Coordinate systems for Land Cover data and Watershed boundaries

The Spatial Reference for the NLCD2001 data is: USA_Contiguous_Albers_Equal_Area_Conic_USGS_version. If necessary, reproject your watershed data to match this coordinate system. This can be done using the 'Project' tool in ArcToolbox, found under Data Management Tools -> Projections and Transformations ->

Feature -> Project. This is a very important step as none of the following calculations will produce accurate results without data that is spatially coincident.

3) Overlay the three Land Cover layers with your watershed layer in ArcMap and visually inspect for overlap and spatial reference errors



4) Extract grass and cropland from the NLCD Land Cover type product

The category definitions for the landcover*.img layer can be found in any of the metadata folders that appear when you unzip the data in your workspace (in multiple formats). For grassland, the categories are 71 and 81. For croplands, use category 82.

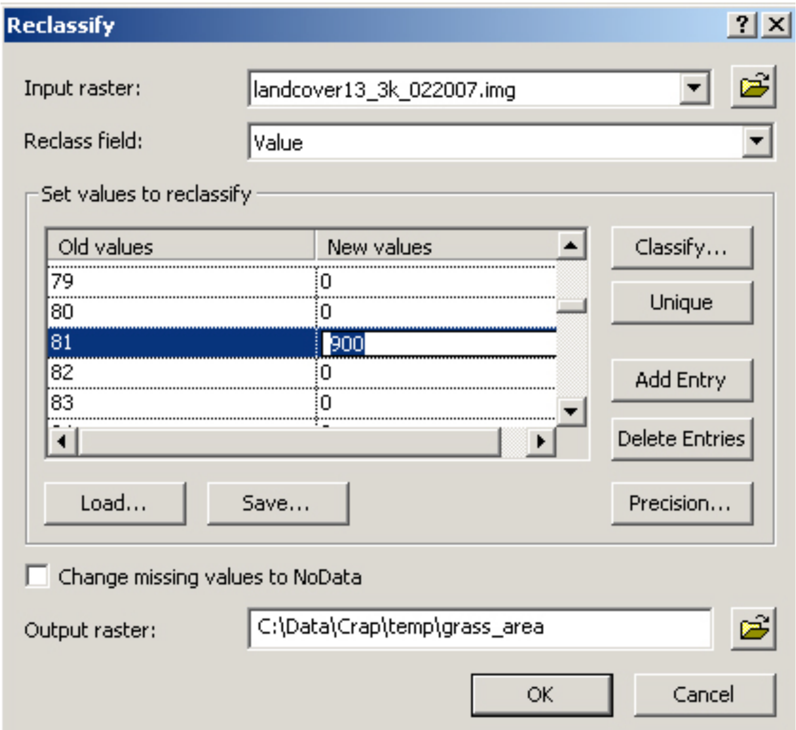
If you haven't done so already, add the Spatial Analyst Toolbar to ArcMap by going to View -> Toolbars and check Spatial Analyst (note, this extension may also need to be activated by going to Tools -> Extensions and checking the Spatial Analyst check box).

On the Spatial Analyst toolbar, click on the dropdown menu and select Options. Then set your working directory in the General tab and set the Analysis mask to your watersheds layer. Under the Extent tab, set the extent to your watersheds layer as well. Click OK.

Next, click on the dropdown menu again and select Reclassify. In this dialog box add landcover*.img as the Input raster and Value as the Reclass field. Change all the New Values to 0 with the exception of 71 and 81, change these to 900 (the area in meters of grassland in a full 30m x 30m pixel). Name the output raster 'grass_area'.

Click OK to run the Reclass tool.

Do the same to create the crop_area layer. Change all the values of the new output raster to 0, with the exception of value 82 which you should change to 900.



5) Convert canopy and impervious surface layers to area rasters

In the Spatial Analyst dropdown menu, choose Raster Calculator. In the Raster Calculator dialog box enter this formula (exactly as typed below):

isa_area = ([impervious.img] * .01) * 900

(change impervious.img to your specific impervious sufaces layer name). This formula multiplies the continuous 0-100 percent impervious surfaces cell values by .01 and then by the area (in m^2) of the cell to get the area of impervious surfaces per cell.

Do the same for the canopy raster:

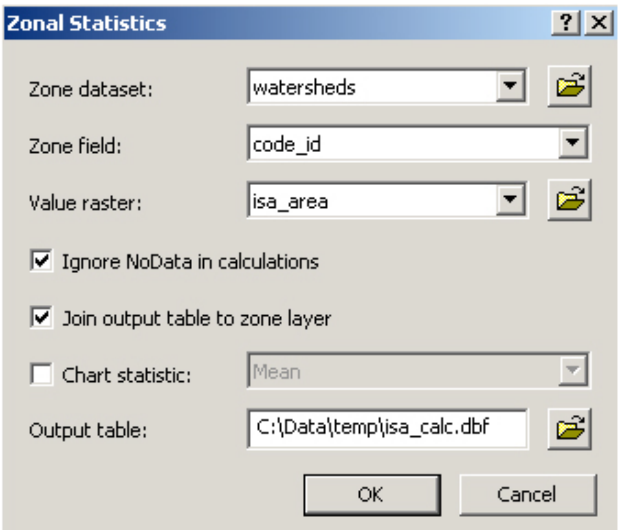
tree_area = ([canopy.img] * .01) * 900

(changing the canopy.img label to your specific canopy layer name)

Watershed Processing

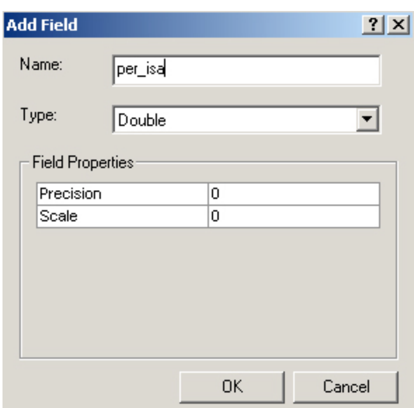
6) Use Zonal Statistics to aggregate land cover statistics per watershed

On the Spatial Analyst toolbar, click on the dropdown menu and select Zonal Statistics. In the Zonal Statistics dialog choose the watersheds layer as the Zone data set, a numeric unique field for the Zone field (if one does not exist in the table cancel this tool and create one, in the example show below it is called ‘code_id’), choose isa_area as the Value raster, check the box that says ‘Join output table to the zone layer’, uncheck the ‘Chart statistic’ option, and label the output table as isa_calc.dbf.



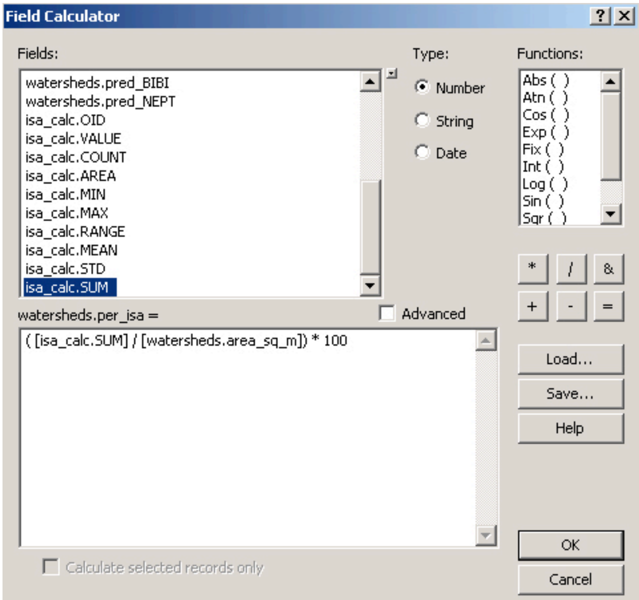
Running this function will add complete statistics to the attribute table of your watersheds layer. Right click on the watersheds layer in the ArcMap table of contents and select Open Attribute Table to see the results. A useful statistic is the new field labeled ‘Sum’. This is the total amount of impervious surface cover per watershed feature.

Now add a field to the attribute table and label it ‘per_isa’ for percent impervious surfaces. To do this, click on the Options button at the bottom of the attribute table and select Add field. In the Add field dialog type per_isa for the field name and select type Double.



Next, to calculate the percentage of impervious surface area by feature, right click the new per_isa column heading in the attribute table and click ‘Field Calculator’. Enter this formula:

([isa_calc.SUM] / [watersheds.area_sq_m]) * 100



Where:

isa_calc.SUM = the new sum statistic from the zonal_statistics function

watersheds.area_sq_m = can be replaced with any field in your table that has the area of each watershed in m^2

Finally, undo the join table between the watersheds attributes and the zonal_statistics by right-clicking the watersheds layer in the table of contents

-> Joins and Relates -> Remove Joins -> isa_calc

7) Repeat step 6 for the remaining land cover statistics (canopy, grassland, cropland)

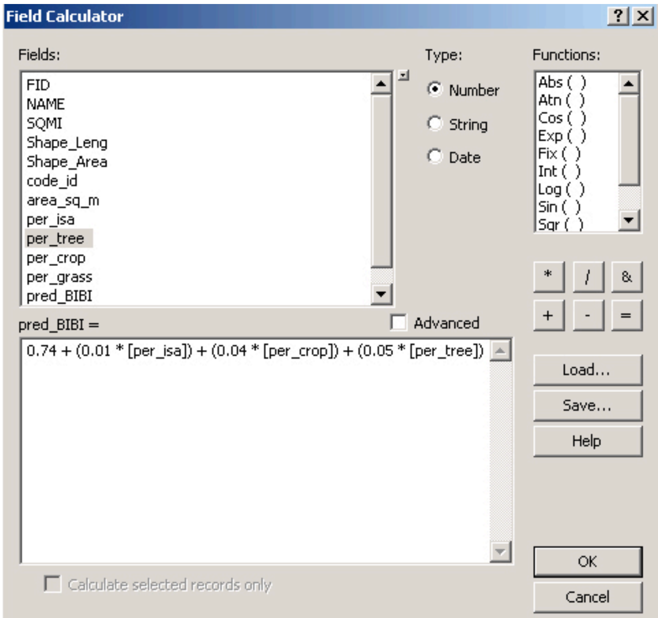
Repeat each part of step 6 to create 3 more fields in your attribute tables labeled per_tree, per_crop, and per_grass.

8) Enter the BIBI and nEPT model forumlas

Add two additional fields to your watersheds layer attribute table and label them pred_BIBI and pred_nEPT (make the type = ‘Double’).

Use the field calculator (as before) to plug in the regression model that is best suited to your study area. An example for predicting BIBI in the Piedmont physiographic region is:

pred_BIBI = 0.74 + (0.01 * [per_isa]) + (0.04 * [per_crop]) + (0.05 * [per_tree])



An example for predicting nEPT in the Piedmont physiographic region is:

pred_nEPT = − 6.72 + (0.33 * [per_tree]) + (0.17 * [per_crop]) + (0.11 * [per_grass])

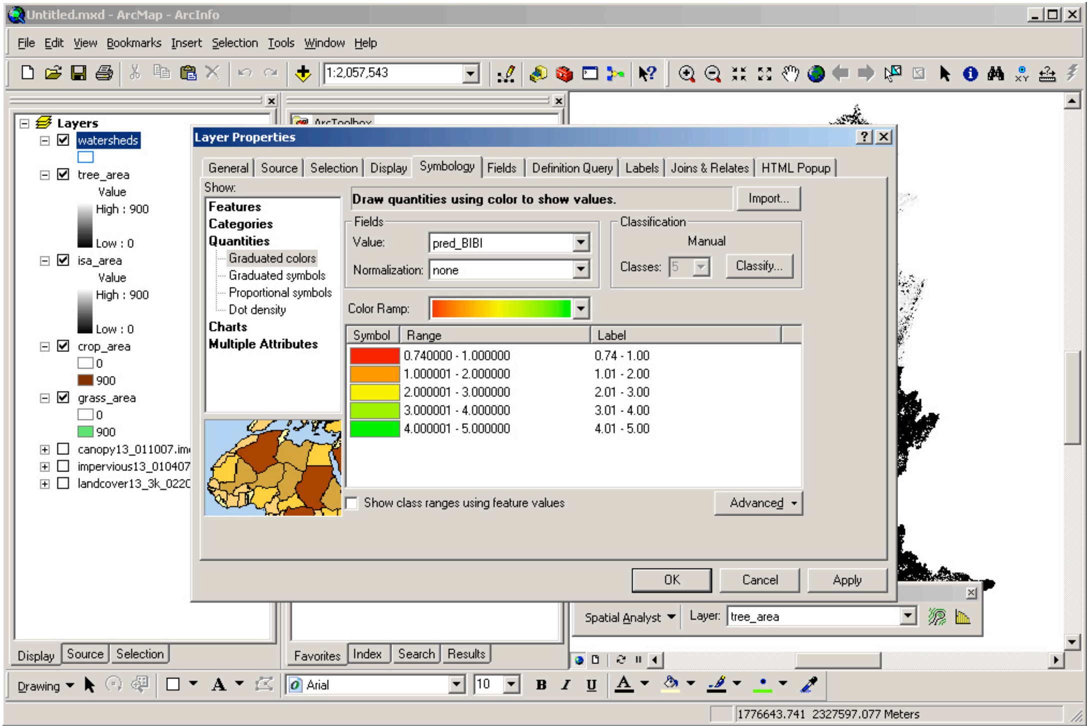
Additional models for other regions and variations of the Piedmont model used above are described more fully and can be found in Table 2 of Goetz and Fiske (2008).

Mapping

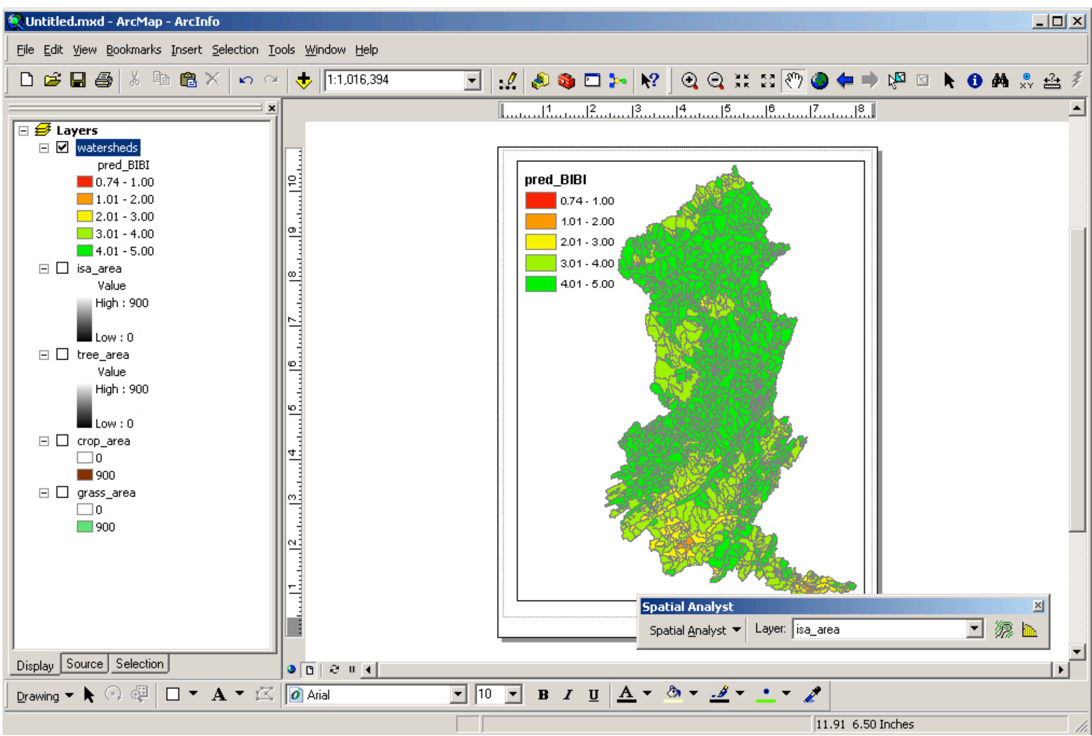
9) Map the predicted BIBI and nEPT

In the ArcMap table of contents, double click on the watersheds layer to bring up the Layer Properties dialog box.

Click on the Symbology tab. Select Show: Quantities -> Graduated colors and Fields Value -> pred_BIBI (or pred_nEPT). Then color and classify as desired.



Switch to the Layout view in ArcMap and map your predicted values. For example, it will look something like this:



Conclusion

There are several ways to navigate the previous 9 steps, and the user should explore the effect of using different models. What is presented here is a straightforward approach using widely available ESRI® ArcGIS software. To speed up this approach, one may experiment with the ArcGIS model builder to automate some of the time consuming tasks (like calculating land cover statistics per watershed). All of the Spatial Analyst tools used here are also available in ArcToolbox, allowing for easy model building. Also, Visual Basic (ArcObjects) and/or Python scripting can be used within ArcGIS software to streamline any or all of these steps.

The models presented here are based on best available data sets, but predictions of any model need to be tested with observations. If stream data exist for your study area, comparisons with these predictions will help to develop confidence in the derived products, allow one to select models that best match local observations, and possibly allow the user to refine the models through additional iterations and stream data sets.

Literature Cited

Goetz, S. J., and G. Fiske. 2008. Linking the diversity of stream biota to landscapes in the mid-Atlantic USA. Remote Sensing of Environment 112:4075-4085

Roth, N. E., M. T. Southerland, G. M. Rogers, and J. H. Vølstad. 2004. Maryland biological stream survey 2000-2004. Volume III: Ecological Assessment of Watersheds Sampled in 2002. Report CBWP-MANTA-EA-04-1, Maryland Department of Natural Resources, Annapolis.